BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE INSTRUCTION 32-1062

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Civil Engineering

ELECTRICAL POWER PLANTS AND GENERATORS

COMPLIANCE WITH THIS PUBLICATION IS MANDATORY

OPR: HQ AFCESA/ENE
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This instruction implements the generated electrical power portion of AFPD 32-10, *Installations and Facilities*. It provides acquisition, operation, and maintenance requirements for electrical generating plants and individual real property installed equipment prime, standby, and emergency generators. It also covers the mandatory requirements of a generator maintenance program. This instruction applies to all personnel who operate and maintain RPIE electric generators. It emphasizes safe, cost-effective, reliable, and environmentally compliant methods and practices. Users should send comments and suggested improvements on AF Form 847, **Recommendation for Change of Publication**, through major commands to HQ AFCESA/ENE, 139 Barnes Dr, Suite 1, Tyndall AFB FL 32403-5319.

SUMMARY OF REVISIONS

This revision incorporates the directive guidance formerly in AFR 91-45, *Management of Electrical Power Plants and Generators*; standardizes technical contents with AFP 91-46, *Maintenance and Operation of Electrical Power Generator Systems*; and retains mandatory information with examples in attachments.

1. Responsibilities Assigned. The Chief of the Civil Engineer Operations Flight ensures:

1.1. Personnel operate and maintain power generation equipment in an efficient and cost-effective manner, following the manufacturers' technical information and recommendations as a minimum.

1.2. The safety of personnel and equipment by following industrial and electrical safe practices (see AFOSH 127-10, *Civil Engineering*, and AFI 32-1064, *Electrical Safe Practices* (formerly AFR 91-12)).

1.3. Compliance with environmental legislation and regulations, particularly concerning restrictions on air emissions; petroleum, oils, and lubricants (POL); and polychlorinated biphenyls.

2. Acquiring Equipment. Engineering flight design engineers or operations flight maintenance engineers must perform an engineering study to determine feasibility before acquiring, replacing, or upgrading power generation equipment. The study must evaluate the following:

- Fault current.
- Quantity and quality of available power.
- Power reliability requirements.
- Load-flow.
- Availability history.
- Paralleling requirements.
- Commercial power interfacing.
- Selective coordination of protective devices.
- Load-shedding plan.
- Impending operational changes.
- Environmental restrictions (for example, new emission source requirements).

3. Training. Base civil engineer operations flight chiefs must ensure base operators and maintenance craftspersons receive training to qualify them for their duties. They must be technically competent and thoroughly familiar with safe practices in AFI 32-1064, AFOSH 127-10, and AFOSH 127-45, *Hazardous Energy Control and Mishap Prevention Signs and Tags*.

The flight chiefs:

- Provide training through government and private industry training schools and seminars.
- Involve trainees when special temporary duty teams make repairs.
- Advise base operators and maintainers of operating permit restrictions.
- Provide ancillary training to non-power production personnel assigned to operate emergency power generators (see chapter 7, AFCAT 36-2223, *USAF Formal Schools*).

4. Technical Data and Procedures. Consult responsibilities contained in AFI 32-1063, *Electric Power Systems* (formerly AFR 91-4) for additional information.

4.1. Power Plant Equipment O&M Manuals. The engineering flight chief and operations flight chief, during contract procurement or in-house purchase respectively, must obtain the:

- Complete set of technical orders or manufacturers' operation and maintenance procedures, recommended maintenance schedules, and parts manual for each make and model of engine and plant equipment acquired.
- Manufacturer's recommended modifications and instructions for using JP 5-8 fuels in each specific engine type.

Power production personnel will develop and document suitable schedules and procedures when manufacturers' information is not available, or to improve them to suit the specific situation. Consult chapter 7 of AFI 32-1063 for additional requirements concerning maintaining, testing, and exercising engine-generators.

4.2. Performance Data. Maintenance engineering or power production personnel must obtain performance data recorded during the manufacturer's shop test or during initial operation on location. Data may be in either in graphic or tabular form. Establish a baseline with this data against which to evaluate future engine performance. Minimum data must include:

- Average cylinder exhaust temperature.
- Air pressure in engine intake manifold in kilopascals (kPa) or pounds per square inch (psi).
- Compression and firing pressures in kPa or psi.
- Fuel pump rack position.
- Fuel consumption at 1/2, 3/4, full load, and 10 percent overload.
- Emissions data for operation at prescribed load levels when needed to obtain operating permits.

4.3. Schematic Diagrams. Operations flight chiefs ensure to:

4.3.1. Develop and maintain detailed mechanical single-line diagrams of the plant and auxiliary piping systems including water, oil, air, and fuel.

- Show emergency arrangements with the positions of controls (for example, valves) positively identified for normal and emergency operation.
- Include alarm and safety systems and identify reset operations.
- Post copies of the diagrams in the plant for personnel to use.

4.3.2. Develop and maintain detailed electrical single-line diagrams to include:

- Normal and emergency switching arrangements.
- Positively identified switch and circuit breaker positions.
- Notes, legends, and cautions as they apply to special equipment (for example, interlocking circuit breakers).
- Switching instructions when switching operations must pass through a central load dispatcher.
- Posting copies of the diagrams in the plant for personnel to use.

4.3.3. Affix a mimic bus with circuit breaker open-close indicating lights to the front of the switchgear and switching stations to assist in both normal and emergency operations. This single-line diagram improves human interaction with the electric system. Opening or closing the wrong switch can cause the loss of the entire power system, and can be a hazard to personnel.

4.4. Operating Procedures. Maintenance engineers and power production personnel must develop and post the following based upon manufacturer's recommendations with modifications and supplements to suit specific local conditions and equipment:

- Standard, step-by-step, operating procedures.
- Emergency stopping procedures, including shutdown of runaway engines.
- Environmental permit restrictions.

Review and update the procedures at least annually.

5. Record Keeping and Analysis. Base power production personnel and maintenance engineers maintain and analyze operation and maintenance records to ensure the mission receives support and equipment follows minimum life-cycle cost trends. Follow major command policy covering who gets distribution of records, when they review the records, and how the reviewer provides feedback to base personnel. Consult administrative personnel on procedures for the maintenance and disposal of records.

5.1. Operating Logs. Generator operators record system performance during regular operation, inspection, and testing. Fill out a form for each scheduled generator run at prime power plants, each scheduled emergency generator exercise, and each unscheduled power outage. Only one form is necessary for each event. Keep a completed copy where maintenance personnel can find it easily and another copy at the plant or generator unit. Use the following forms:

5.1.1. AF Form 487, **Emergency Generator Operating Log (Inspection and Testing)**, or other MAJCOM-approved form for standby plants requiring hourly monitoring. Record the following information as a minimum:

- Operating data.
- Condition of lube oil (viscosity test).
- Condition of plant and subsystems.
- Deficiencies.
- Corrective measures.

5.1.2. AF Form 1167, **Daily Power Plant Operating Log (Diesel - Electric)**, for prime power plants and if the running time for standby power plants exceeds 8 hours.

5.1.3. AF Form 3509, **Daily Power Plant Operating Log (Gas Turbine - Electric)**, for steam and gas turbines when appropriate.

5.1.4. A custom log developed and used when the standard log is inadequate. Tell HQ AFCESA/ENE what improvements you made and provide a copy of the log.

5.2. Maintenance Records. Record data during inspections and maintenance that measure equipment condition and wear rates. Review this data periodically and when scheduling maintenance activities. Use the following forms to record the data:

- AF Form 731, **Crankshaft Deflection Record**.
- AF Form 734, **Cylinder Liner and Ring Wear Record**.
- AF Form 3507, **Diesel Engine Inspection Data**.
- AF Form 3508, **Diesel Cylinder Compression and Firing Tests**.
- AF Form 3510, **Automatic Transfer Switch Inspection/Maintenance Report.**

5.3. Analyzing Performance. Monitoring engine performance data detects gradual changes that signal engine deterioration. Plot essential data versus time to graphically reveal performance trends. You must include, as a minimum, the following data to plot: compression pressure, cylinder firing pressure, exhaust temperature, crankcase pressure (vacuum), lube oil consumption, and fuel consumption.

5.4. Power Plant Log Book. In addition to AF Form 1167, maintain a log book at each plant to enter other pertinent information. Use it to record time of events, nature of abnormalities and malfunctions,

physical measurements taken, adjustments made, oil samples taken, oil changed, maintenance performed, and weather information.

5.5. Historical Records. Maintain AF Form 719, **Historical Record Diesel Electric Generators and System**, at the maintenance organization. Use it to show the date, the cumulative number of engine operating hours, a description of all maintenance and inspections, and parts replaced. When transferring a generator set from one organization to another, send the associated historical records with it.

6. Operation. Users operate units within manufacturers' recommended speed (revolutions per minute), load limits, temperatures, and pressures, except in emergency situations. Extended overload or underload reduces engine efficiency, increases maintenance requirements, and may damage the unit. Record all readings hourly. Watch for any abnormalities (for example, leaks, unusual noises, or vibrations). Promptly take corrective action and record it in the log. Do not exceed operating permit restrictions. Incorporate typical operating requirements from **Attachment 2** into operating and inspection procedures for diesel-electric generators.

7. Maintenance. Power production personnel follow manufacturer's recommendations on scheduling and maintenance procedures unless local conditions and operations justify deviations. Base scheduled engine overhauls on actual operating data, not on manufacturer's recommendations. Follow AFI 32-1063 guidance for exercising power generation equipment as part of a sound maintenance program. Follow safe practices and clearance procedures in AFI 32-1064 and take proper precautions against accidental or unintentional starting when working on an engine. Use AF Form 979, **Danger Tag**, and AF Form 982, **Do Not Start** (see AFOSH 127-45). See Institute of Electrical and Electronics Engineers (IEEE) Standard 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications,* for a typical maintenance schedule for emergency or standby systems; **Attachment 3** for typical inspection and maintenance requirements for power plants by system; and **Attachment 4** for typical inspection checklists and schedule for prime and continuous duty (class A) units.

8. Preparation for Storage. Preserve engines stored for more than 60 calendar days.

8.1. Block off air and exhaust inlets to prevent air and moisture from entering the internal parts of the engine.

8.2. Preserve corrodible exterior surfaces not protected by paint, galvanizing, or plating with a thin film of rust-preventive compound. Be sure compounds conform to current military specifications.

9. Fuels. Use fuel oils meeting Federal Specification VV-F-800C, *Fuel Oil, Diesel,* covering fuel grades DF-A, DF-1, DF-2, or type I and II. Follow the specific temperature and applicable service conditions and make sure sulfur content does not exceed environmental restrictions. Do not mix different grades of fuel. Consult TO 42B-1-1, *Quality Controls of Fuels and Lubricants,* and MIL-HDBK 200, *Quality Surveillance Handbook for Fuels, Lubricants and Related Products,* for additional information. Before using jet fuels, consult the engine manufacturer to determine the proper modification and parts needed for proper engine operation. Follow applicable environmental reporting and cleanup procedures in case of spills and leaking storage tanks.

10. Lubricating Oils. Follow the engine manufacturer's recommendations for the type and grade of oil as closely as possible. Lubricating oils meeting minimum MIL-L-2104, *Lubricating Oil, Internal Com-*

bustion Engine, Combat/Tactical Service, and MIL-L-46167, *Lubricating Oil, Internal Combustion Engine, Arctic,* military specifications are acceptable for many diesel engines. However, these specifications may not be adequate for some modern high speed engines. Confirm suitability of military specification lubricating oils with the engine manufacturer before use. Change oil and analyze samples at scheduled intervals.

11. Special Tools and Equipment. Maintain necessary tools, equipment and instruments as authorized in Table of Allowances (TA) 489, *Civil Engineering Generator Sets and CE Maintenance Equipment for Diesel Engines, Generators, Solid State Uninterruptible Power Supplies, and Arresting Barriers*. Use the basis of issue and the TA preface to determine requirements. Request changes to the TA when allowances are inadequate, excessive, or the equipment can not support the local mission.

12. Materials and Repair Parts:

12.1. Supply. Establish and maintain an adequate supply of materials and repair parts. Follow methods and procedures for procuring, handling, storing and accounting of supplies and equipment in AFM 23-110, *USAF Supply Manual* (formerly AFM 67-1).

12.2. What To Store. Determine the type and quantity of parts, tools, and materials required for bench stock, supply point, special levels, and equipment accounts, based on the following factors:

- Plant or system classification.
- Number of identical systems or components maintained.
- Level of maintenance capability (depot, intermediate).
- Materials required for frequently encountered minor repairs.
- Low failure rate, long lead items that can incapacitate the system without ability to bypass or substitute in an emergency situation (for example, governors and fuel injectors).
- Geographical separation from supplier, particularly overseas units.

13. Forms Prescribed. This publication prescribes the following forms:

- AF 487, **Emergency Generator Operating Log (Inspection and Testing)**
- AF 719, **Historical Record Diesel Electric Generators and System**
- AF 731, **Crankshaft Deflection Record**
- AF 734, **Cylinder Liner and Ring Wear Record**
- AF 1167, **Daily Power Plant Operating Log (Diesel - Electric)**
- AF 3507, **Diesel Engine Inspection Data**
- AF 3508, **Diesel Cylinder Compression and Firing Tests**
- AF 3509, **Daily Power Plant Operating Log (Gas Turbine - Electric)**

- AF 3510, **Automatic Transfer Switch Inspection/Maintenance Report**

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The Civil Engineer

Attachment 1

GLOSSARY OF REFERENCES, ABBREVIATIONS, ACRONYMS, AND TERMS

References

AFCAT 36-2223, *USAF Formal Schools* (formerly AFR 50-5)

AFI 32-1063, *Electric Power Systems* (formerly AFR 91-14)

AFI 32-1064, *Electrical Safe Practices* (formerly AFR 91-12)

AFMAN 23-110, *USAF Supply Manual* (formerly AFM 67-1)

AFM 67-23, *Standard Base Supply Customer's Guide*

AFOSH 127-10, *Civil Engineering*

AFOSH 127-45, *Hazardous Energy Control and Mishap Prevention Signs and Tags*

AFOSH 127-66, *General Industrial Operations*

AFOSH 161-1, *Respiratory Protection Program*

Federal Specification VV-F-800, *Fuel Oil, Diesel*

IEEE Standard 446, *Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications*, The Institute of Electrical and Electronics Engineers, Inc., 345 East 47th St., New York NY 10017-5000

MIL-HDBK 200, *Quality Surveillance Handbook for Fuels, Lubricants and Related Products*

Military Specification MIL-C-10597, *Cleaning Compound with Conditioner and Inhibitor for Engine Cooling Systems*

Military Specification MIL-L-2104, *Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service*

Military Specification MIL-L-46167, *Lubricating Oil, Internal Combustion Engine, Arctic*

NFPA 70B, *Electrical Equipment Maintenance*, National Fire Protection Association, 1 Batterymarch Park, Quincy MA, 02269-9101

TA 489, *Civil Engineering Generator Sets and CE Maintenance Equipment for Diesel Engines, Generators, Solid State Uninterruptible Power Supplies, and Arresting Barriers*

TO 42B-1-1, *Quality Control of Fuels and Lubricants*

Abbreviations and Acronyms

AFCAT—Air Force Catalog

AFOSH—Air Force Occupational Safety and Health Standard

IEEE—Institute of Electrical and Electronics Engineers

ISO—International Organization for Standardization

kPa—Kilopascals, unit of pressure per unit area (1 kPa = 0.1450376 psi)

kW—Kilowatts, unit of actual (real) power produced by an electric generator

MIL-HDBK—Military handbook

NFPA—National Fire Protection Association

O.D.—Outside diameter

POL—Petroleum, oils, and lubricants

psi—Pounds (pounds-force) per square inch

RPIE—Real property installed equipment

rpm—Revolutions per minute

SOP—Standard operating procedures

SSUPS—Solid state uninterruptible power systems

TA—Table of allowances

TO—Technical order

var—Volt-ampere reactive

Terms

Adjusted Stock Levels—The stock of rarely used items (for example, emergency standby equipment). Base supply keeps most of these items in stock and requires periodic justification.

Auxiliary Power—Backup power for the primary power normally provided by a commercial utility.

Availability—The long term probability of success with repair and scheduled maintenance of electrical power plants, generators, and power systems. Calculate availability as the ratio in percentage of total period minus repair downtime minus maintenance downtime to total period. The calculation assumes power generated meets quality standards.

Bench Stock—A group of items required to perform routine, recurring work and items required for the most frequently encountered emergencies used regularly by maintenance personnel and usually in close proximity to the maintenance area.

Circuit Breaker—A mechanical switching device capable of making, carrying, and breaking currents under normal circuit conditions and also, making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions (for example, short circuits). The interrupting rating must be larger than the largest expected abnormal condition. Circuit breakers may be oil, vacuum, or air type.

Class A Power Plant—Generates power on a continuous basis (over 4000 hours annually) and serves as the sole or primary source of power. Class A plants usually have 100 percent generated power plus one standby reserve unit and one maintenance reserve unit.

Class B Power Plant—Provides power on a standby basis for a significant number of hours each year (between 1000 and 4000 hours annually) usually at sites that anticipate months of continuous operation. Class B plants usually have 100 percent generated power for technical and selected essential nontechnical loads plus one standby reserve unit. Class B plants for critical missions often have a second standby reserve unit. A commercial power usually supplies the primary power at Class B locations.

Class C Emergency Power Plant—Consists of at least one quickstart units to cover prime power outages (less than 1000 hours annually). The units have manual or automaticstart.

Class D Emergency Power—Uninterruptible (no-break) power using stored energy to provide continuous power within specified voltage and frequency tolerances.

Continuous Power—(International Organization for Standardization (ISO) Engine Classification) Power that a generator can continuously deliver for an unlimited number of hours per year while following the manufacturer's stated maintenance intervals. Load rating is continuous or nonvarying. Normally, a generator can operate at 110 percent of this rating for a limited periodusually 1 hour, with or without interruption, within a 12-hour period of operation. However, some generators do not offer overload capability and designers have to specify it if required.

Control Device—An individual device that governs the performance of any electric apparatus, machine, or system.

Disconnecting Switch—A mechanical switching device used for changing the connections in a circuit or system or for isolating a circuit or equipment from the source of power. It has no interrupting rating (opens or closes the circuit only when negligible current is flowing) and operates after another mechanism opens the circuit.

Limited Time Running Power—(ISO Engine Classification) The maximum power a generator can deliver for up to 300 hours per year following manufacturer's stated maintenance intervals. This classification applies to a limited time operation with no overload capability, and uses the standby rating. The generator can operate at the limited time running power rating for more than 300 hours per year. However, engine wear will increase and the timetooverhaul (number of operating hours) or engine life will decrease. Limitations may also exist on continuous operating hours or run time.

Prime Power—(ISO Engine Classification) The maximum power available during a variable power sequence, which may run for an unlimited number of hours per year while following manufacturer's stated maintenance intervals. The permissible average output during a 24hour period can not be more than a specified percentage of the prime power rating. The manufacturer establishes this percentage, typically 8090 percent. Prime power is a continuous operation with variable load rating. As with the continuous power rating, some generators also have a 10 percent overload capability, which designers may specify if required.

Protective Device—An individual device operating singly or with other devices that detects abnormal conditions in the electric system and takes control action to prevent damage and injury.

Reliability—The long term probability of success with repair of failed components but without scheduled maintenance of electrical power plants, generators, and power systems. Calculate reliability as the ratio in percentage of the mean time between failure minus the mean time to repair to the mean time between failure. This quantitative measure more nearly represents the power system during critical periods of operation than any other quantitative measure. Another phrase for this term is "inherent availability."

Supply Point—A storage location having items owned and controlled by base supply. Civil engineer units must justify these low usage, expendable items as specifically related to the needs of the organization and near the activity supported. Supply points may normally keep any supply item except equipment items.

Switchgear—An indoor or outdoor metal structure containing electrical switching and interrupting equipment with buses and connections and associated control, instrumentation, metering, protective, and

regulating devices. The associated devices are in separate grounded metal compartments from the switching and interrupting equipment.

Attachment 2

TYPICAL OPERATING REQUIREMENTS DIESEL ENGINE GENERATING PLANTS

A2.1. Unit Operation:

A2.1.1. Prior to Starting. Perform a pre-start inspection.

- Make sure any switching and automatic control equipment is in the correct position.
- Check all fluid levels. Thoroughly check the lubricating system. Check sump level and filters and fill if necessary. If the engine has a separate oil pump, prime it. Check hydraulic governor oil. Check coolant level.
- Visually inspect for loose connections, leaks, and cracked hoses.
- Inspect parts of engine system after any work; make sure work is complete and covers are in place.
- Check all moving engine parts to see that they are clear for running.
- Make sure all tools and other maintenance items are clear of the unit.
- For cold weather operation, make sure oil, coolant, and/or jacket heaters are operating or follow recommended warm-up procedures.
- Check all alarm and shutdown indicators ("lamp test").
- Inspect the fuel oil service tank for water or sediment. Vent all air from fuel system using vent cocks.

A2.1.2. During Operation:

- Maintain temperatures and pressures within manufacturer's recommended normal limits. Record readings hourly. Frequently monitor system voltage and frequency.
- Check the oil level in the sump regularly and check for water and contamination in the sump tank.
- When units are operating in parallel or synchronized with the utility source, make sure all units are sharing load and volt-ampere reactive (var) output properly. Avoid circulating currents that cause unstable alternator operation.
- Watch for any abnormalities such as leaks, unusual noises, or vibrations. Promptly take corrective action. Record the actions in the operating log when time permits.
- If you hear slight explosions in the crankcase, or notice popping of the relief valves, immediately shut down the engine. Do not remove any cover plate until the engine has cooled off. To prevent seizure open the indicator cocks and bar the engine over slowly.
- If you notice overheating, remove the load from the engine as soon as possible. Overload indications include excessive alternator or engine temperature, black smoke from the exhaust, excessive firing pressure, or engine knocking. Idle the engine while investigating the cause of overheating.
- When an engine is ready for normal shutdown, reduce the load gradually to allow the engine to cool gradually. Except in an emergency, allow at least 5 minutes for this process.

A2.1.3. Shutdown. After removing load, continue to run the engine for a short period to allow temperatures to stabilize. Wipe the engine down and make sure it is ready for startup. If batteries are present, check to see if they are at the correct voltage or charging properly. Top off the fuel tank if possible.

A2.2. Diesel Fuel Storage and Handling:

A2.2.1. Handling and Storage. Keep all dirt, dust, water, and sediment out of the fuel. Prevent contamination by reducing the handling of fuel. Fuel delivery to a storage tank and pumping it directly to the engine day tank minimizes handling. Preserve fuel in storage and prevent sludge formation by frequently draining the water from the bottom of tank, and keeping it full especially during cold weather.

A2.2.2. Inspection. Collect a sample in a clear glass bottle from every delivery of diesel fuel to storage, tag the bottle with the date, name and address of the supplier, and cap it tightly. Allow the sample to settle for at least 12 hours and compare it with previous samples for appearance (color), and amount of contaminants such as water, sediment, gasoline or kerosene. If the quality or identity of the fuel is in doubt, send a sample to an approved laboratory for analysis.

A2.3. Fire Equipment. Place dry chemical fire extinguishers conveniently near the engine. NEVER THROW WATER ON THE ENGINE, GENERATOR, AUXILIARY EQUIPMENT, OR SWITCHGEAR.

Attachment 3

TYPICAL INSPECTION AND MAINTENANCE REQUIREMENTS BY SYSTEM DIESEL ENGINE GENERATING PLANTS

Section A3A—Engine

A3.1. Fuel System:

A3.1.1. Fuel Pump and Racks. When the engine is not running, check fuel pump racks, fuel control shaft bearings, and control linkages frequently for smooth motion. Lubricate and move each part back and forth a few times. When a pump malfunctions, replace the pump with a spare, and disassemble, inspect, and clean the components of the removed pump. Replace any worn or scored parts and check for hairline cracks.

A3.1.2. Fuel-Injection Valves (Nozzles). If an injector is not functioning properly, replace it with a spare injector and inspect and clean the removed item. Dirt, water, or excessive heat cause most injection problems.

A3.1.3. Fuel Filters and Strainers. Do not change or clean filter elements when the minimum required fuel pressure to the engine is present and the pressure drop across the filter does not exceed manufacturer's recommendations. To monitor condition of the filter elements and schedule cleaning or replacement, plot pressure drop (kPa or psi) across the filter at regular time intervals (days, weeks, or months).

A3.1.4. Storage Systems. Keep storage tanks clean and well covered. Establish a regular cleaning schedule. Frequently check fuel levels and remove water. Keep all fuel handling equipment (for example, measures, funnels, and containers) very clean and covered when not in use. Periodically check operation of fuel transfer pumps.

A3.2. Engine Governing Systems:

A3.2.1. Governors. The two main requirements for dependable hydraulic governor operation are a vibration-free drive and periodic oil changes. Electronic governors require relatively little maintenance. Keep a spare governor assembly in a prime power plant.

A3.2.2. Linkage. Check governor linkage and connections to the fuel pump racks for excessive play in the pivot bearings. Lubricate these components frequently.

A3.3. Alarm and Shutdown Systems. Temperature and pressure of coolant and lube oil are important indicators of engine performance. Most engines have basic engine protective circuitry and monitoring devices (for example, low lube oil pressure, high coolant temperature, and overspeed). Some have alarms that sound before shutdown to alert the operator to a problem requiring immediate attention. These switches, along with the associated protective circuitry, are important to safe engine operation. Establish a schedule to test alarm and shutdown systems and calibrate them following the manufacturer's specifications.

A3.4. Engine Lubricating Systems:

A3.4.1. Lubricating Oil. Change oil at manufacturer's recommended intervals. Consider operating hours, load and atmospheric conditions, and operating temperature level to adjust those recommendations. Watch for buildup of contaminants (for example, sludge, varnish, water, and fuel dilution). Their presence not only impairs the oil's ability to lubricate, but indicates poor engine performance. Analyze oil samples at every oil change or every 1000 hours of operating time for prime power generators. For standby generators, analyze oil samples every 6 months or every 100 hours of operating time. Check for loss of viscosity, acid content (total acid and base numbers), particulates (dirt, sand, metal and wear particles), water, and other contaminants (fuel and combustion byproducts). Adjust oil change intervals based upon these periodic tests. Limit fuel oil dilution to 5 percent and carbon contamination to 15 percent from the new oil condition.

A3.4.2. Oil Filter. Replace filter elements at recommended intervals. Monitor the pressure drop across the filter between replacements. Clean the filter or replace the elements before the pressure drop exceeds the manufacturer's recommendations and reaches a level at which the bypass will open. Reduce the replacement intervals per operational experience. Check the used filter for signs of abnormal engine wear (bearing and other foreign material).

A3.4.3. Engine Performance Indicators. Use the gradual change of oil pressure at the engine header as an indicator of the wear on engine bearings or of internal oil leaks. Spectrometric analysis (analysis of microscopic bits of metal in the oil) can detect abnormal engine wear. Consult the manufacturer on the results of spectrometric analyses to establish or adjust maintenance intervals.

A3.4.4. Cold Weather Operation. At class B or C power plants located where ambient temperature drops below 60 ^{o}Fahrenheit, preheat engine lube oil to maintain operational readiness. Establish a schedule to check heater operation.

A3.5. Engine Cooling Systems:

A3.5.1. Cooling Water Treatment. Industrial water treatment of the jacket cooling water controls scale from forming deposits that affect operation. For closed systems requiring no makeup water, inhibited antifreeze (ethylene glycol) provides the necessary protection. If necessary for corrosion control, various treatments are available to add to the antifreeze (check with the engine manufacturer first). For example, a blend of sodium nitrite-borax is effective in controlling cavitation corrosion of diesel engine cylinder liners.

A3.5.2. Removal of Scale. Consult the base corrosion control engineer, command corrosion engineer, or HQ AFCESA/ENM before using chemicals to remove scale or corrosion from a cooling system. One packaged treatment using oxalic acid conforms to military specification MIL-C-10597, *Cleaning Compound with Conditioner and Inhibitor for Engine Cooling Systems,* is available through base supply. Check with the engine manufacturer before using any chemical scale or corrosion removers. After cleaning, flush the system thoroughly and immediately add conditioners and then inhibitors to neutralize the chemical removers. Consult with environmental engineering for approved disposal procedures for used chemicals and system water at each step of the process.

A3.5.3. Adding Coolant. Suddenly adding large amounts of cold water to a hot engine can cause cracks in the liners and heads or piston seizure. If you must add coolant to a running engine, add it at a trickle rate.

A3.6. Engine Starting System:

A3.6.1. Air Starting. Establish a schedule to check pressure in the storage tank and operation of the compressor.

A3.6.2. Electric Motor Starting. Use a continuous cranking period of no more than 30 seconds. Equal cranking and rest periods of about 10 seconds up to a minute of cranking cycle is normal. Overheating can damage starting motors if operated continuously for more than one minute.

A3.6.3. Batteries. Keep batteries fully charged at all times. Check specific gravity with a hydrometer and keep terminals clean. Check battery charger operation when inspecting batteries.

A3.7. Air Intake and Exhaust Systems:

A3.7.1. Air Filters. Inspect the filters often to determine the best service schedule. There is no common rule for servicing air cleaners. The type of service depends on the air cleaner, air conditions and the application. Some engines use restriction indicators to signal when the filters require servicing.

A3.7.2. Turbochargers and Blowers:

A3.7.2.1. Turbochargers. Monitor the performance of turbochargers at regular intervals determined from manufacturer's recommendations and operational experience. Maintain lubricating oil temperature and pressure within recommended limits. Keep the turbocharger oil clean by changing the filter element on schedule. Check the water temperature to make sure the temperature rise across the turbocharger stays within manufacturer's limits. Observe the engine to detect any noticeable vibration. If a vibration is present, shut down the unit and determine the cause. If the engine is operating under light load, check the intake manifold for oil fouling. Check the rotor end play and the radial clearance between the turbine blade outside diameter and either the inlet casing or nozzle ring when cold.

A3.7.2.2. Blowers. Establish a schedule to check rotors for abrasions. Check the inlet screen for accumulation of dirt that will affect air flow. Inspect oil seals. Check for loose rotor shaft and damaged bearings. Check for excessive backlash between the blower and the timing gear.

A3.8. Exhaust System. Keep the moisture drain point on the silencer (muffler) clean to prevent moisture accumulation that may cause severe engine damage. Establish a schedule to clean pyrometers and thermocouples.

A3.9. General Overhaul and Repair:

A3.9.1. Common Practices:

- Don't mix engine parts from the same or different engines. Mark for position and tag when disassembling.
- Don't mix cap screws, bolts, and washers from the same or different engines.
- Inspect engine parts carefully for abnormal conditions during disassembly.
- Protect delicate parts and surfaces. Don't pile engine parts together. Apply oil to surfaces subject to rust. Plug off passages likely to accumulate dust, machining chips, or other debris.
- Clean the engine thoroughly. Once clean, keep it clean.
- Work accurately. Use precision gages where needed. Follow tables of limits and tightening torque values.

- Take positive steps to prevent unintentional starts when working on the engine. Block or lock the throttle and attach a safe clearance tag (either AF Form 979, **Danger,** or AF Form 982, **Do Not Start**) to the starting control. Disconnect the starting batteries or close the starter air supply before beginning repairs.
- Follow the manufacturer's recommendations.

A3.9.2. Crankcase Alignment Inspection. Properly align all crankshaft main journals. Check alignment during the original installation and during major inspection periods, or more often if encountering bearing trouble. Deviations from correct alignment usually are due to wear and distortion, excessive wear of one bearing, wear of the associated journal, or crankcase distortion from uneven mounting surface. Record deflection readings on an AF Form 731, **Crankshaft Deflection Record**.

A3.9.3. Bedplate Inspection. Check for shifting of leveling wedges, loose foundation bolts, and deflection of skid mounts. With bedplates, the distortion of bearing saddles is generally a result of irregular support or cracking. Check crankshaft deflection after releveling the bedplate. When crankshaft alignment is difficult to maintain, check the bedplate or crankshaft carefully for possible cracks.

A3.9.4. Checking Crankshaft Thrust Clearance. Maintain thrust clearance at the values and limits recommended in the manufacturer's instruction manual.

A3.9.5. Crankcase Inspection. After placing an engine in service, inspect the crankcase every 24 hours for the first 3 or 4 days. Continue the inspection after taking the engine off the line.

- Check for loose bolts, nuts, cotter pins, and broken lock wires. Also check condition of the camshaft drive gear train.
- Check all main and connecting rod bearings for signs of bearing-metal squeezing out the sides, and for metal discoloration.
- Operate the motor-driven lube-oil pump or hand-priming pump, and check for oil leaks and excessive flow around the crankshaft journals.
- Check for water leaks, especially around the outside of the liners. Operate any motor-driven water-circulating pumps during the water check.
- Check the crankcase for general cleanliness.
- Check the crankshaft oil seal during operation and replace if necessary.

A3.9.6. Inspection of Cylinder Liners. Measure liners for wear and check for dry spots, overheating, and scoring when removing cylinder heads. Record measurements of liner wear on an AF Form 734, **Cylinder Liner and Ring Wear Record**, and retain it as a permanent record. Remove all lacquer and varnish deposits on liners. For slight scoring on a liner, polish it with a fine convex oil stone. If you find that cylinder liner wear and out-of-roundness is within manufacturer's limits and the cylinders are in good condition, do not replace the liners. Liner wear normally occurs most rapidly at right angles to the axis of the crankshaft; therefore, you can often increase liner life by rotating the liner 90 degrees within the block. Follow manufacturer's recommendations for break-in when you install new liners.

A3.9.7. Inspection of Pistons and Piston Rings. Do not remove piston rings from the piston for cleaning or inspection unless evidence indicates excessive wear or piston work needed. Measure and record gap clearance of new rings before installation, and keep measurement records of used rings and

hours of operation on an AF Form 734. The measurements serve for establishing ring wear and wear rates. After replacing rings, follow manufacturer's recommendation for break-in.

A3.9.8. Inspection of Oil Control or Scraper Rings. Inspect the scraping edge of the rings closely. If the land width of the used ring is about twice as wide as the land of a new ring, or if nicks or burrs are present, replace the ring. Make sure that carbon or sludge does not clog the drain holes in the ring grooves of the piston.

A3.9.9. Bearing Inspection. A drop in lube oil pressure to the engine, cranking speed changes, or crankshaft web deflection may indicate changes in bearing clearances. Foreign material and bearing material found in the lube oil filters or crankcase definitely indicate bearings in distress. Methods used for checking bearing clearance vary widely with engine size. Check main and connecting-rod clearance on small high-speed engines using strips of "plastigage." You may also use a dial indicator to check connecting-rod bearing clearance. An advantage to this method is that it does not require dismantling or disturbing the bearing. If there are frequent connecting rod bearing failures, check the respective connecting rods for straightness and bearing-bore out-of-roundness. Check main bearing clearance using feeler gauges. If installing only one new bearing, break it in gently by idling the engine for about 1 hour and checking for overheating. If replacing all bearings, break them in gradually on several short runs at light load with an inspection of the temperature by hand touch after each run. Take crankshaft deflection readings after any bearing change.

A3.9.10. Crankshaft Size. Follow the manufacturer's manual for allowable limits on wear and out-of-roundness of crankshaft pins and journals. Where bearing failure scores or grooves crankshaft pins and journals, smooth the surfaces before installing new bearings and after checking that wear and out-of-roundness are not beyond the manufacturer's recommended limits. However, if not within manufacturer's limits and excessive scoring exists on the bearing surfaces, replace the shaft. Send the damaged shaft of engines 250 kilowatts (kW) and over in capacity to the factory for chromium plating. Chromium-plated shafts are much harder than carbon steel and the bearing pins and journals of the plated shaft are brought back to their original size. The chromium-plated shaft can then serve as a spare for the plant.

A3.9.11. Generator Alignment. Follow the manufacturer's instructions for aligning generator and engine. Follow good alignment practices including proper shimming, correct torque on hold-down bolts, accurate dial indicator usage, allowances for bearing clearances, thermal growth, and other characteristics of the specific engine.

A3.9.12. Startup and Break-In after Overhaul. Follow the manufacturer's instructions for startup and break-in after overhaul or replacing major components (for example, cylinder liners, pistons and rings, and main and connecting-rod bearings).

Section A3B—Generator

A3.10. Brush Type Exciters. Use compressed air to blow out accumulated carbon, dust, and dirt. Pay particular attention to the area behind commutator necks. Develop a schedule to check and maintain the following items:

- Drive belts (condition and tightness).
- Commutator brushes [axial position, excessive arcing and chattering, and wear (replace when about half original length)].

- Bearing lubricant.
- Commutator (roughness, hard spots, and out of round condition).
- Electrical connections.

A3.11. Alternator. Perform routine inspections and spot checks per the manufacturer's recommendations. Use a strobe light to inspect the condition of rotating parts during operation. Check for loose stator iron, and the condition of the rotor wedges and bolts. Inspect bolts to be sure they are tight.

A3.11.1. Windings. Inspect exposed insulation periodically and keep it clean and dry. Operate generators under load at least once each month to be sure the windings are in good condition. Run them more frequently when the relative humidity is high. Otherwise, place heating lamps or heating resistors near the windings to keep them dry. Use compressed air or solvents to remove dirt, grease and oil. WEAR SAFETY GLASSES OR APPROVED FACE SHIELD AND AN APPROVED RESPIRATOR WHEN USING COMPRESSED AIR FOR THIS PURPOSE. EXERCISE CAUTION TO AVOID DIRECT PERSONAL CONTACT WITH THE COMPRESSED AIR BLAST. Most cleaning solvents are toxic and may be flammable. Refer to AFOSH 127-66, *General Industrial Operations,* for information on the safe handling of solvents and to AFOSH 161-1, *Respiratory Protection Program,* for threshold limit values of airborne contaminants. Also consult the manufacturer's manual for compatibility with the generator insulation. After cleaning, dry the parts and revarnish them with an approved insulating varnish.

A3.11.2. Insulation Testing. Perform periodic electrical insulation resistance tests using a megohmmeter to determine the quality of armature and alternator field winding insulation, the contamination level of insulation by moisture, dirt or carbon, and to indicate the need for planned reconditioning before service failure. Test immediately following generator shutdown when the windings are hot and dry.

A3.11.3. Outboard Bearings. Check the temperature of the outboard bearing by hand touch and the oil level in the bearing every hour. Change the oil every 6 months or 4000 hours of operation for class A units and every year for class B and C installations.

A3.11.4. Collector Rings and Brushes. Check for sparking which indicates improper brush and alternator-collector performance. Check the alignment of brushes on the ring periodically to make sure that a brush does not overhang the edge of the ring. Keep collector rings, brushes, and brush holders clean and free from carbon, dust, and oil. See that all brushes move freely in their holders. Remove sticking brushes and rub their sides with fine sandpaper. Thoroughly clean brush holders and collectors. Tighten any loose parts of the brush rigging. Check for proper spring tension. Remove black spots on the surface of the collector rings by carefully polishing the surface lightly with fine sandpaper and crocus (a special abrasive) cloth. Tolerate light mottling after polishing. If rings become particularly rough, polish them with the unit running at idle speed. Use a dial indicator on the back of a brush while the unit runs at slow speed to check the roundness of rings. When the check indicates eccentricity, grind and polish the rings. Occasionally reverse the polarity of rings.

Section A3C—Switchgear

A3.12. Switchgear Defined. Switchgear is a general term covering switching and interrupting devices that control, meter, and protect the flow of electric power. The component parts include circuit breakers,

instrument transformers, transfer switches, voltage regulators, instruments, protective relays and devices, and associated interconnections and supporting or enclosing structures.

A3.13. Switching and Interrupting Devices and Control Relays. See AFI 32-1063 for required exercising intervals and National Fire Protection Association (NFPA) 70B, *Electrical Equipment Maintenance*, for typical maintenance requirements. Follow manufacturer's recommended procedures for the specific items.

A3.14. Voltage Regulator. Follow the manufacturer's literature for specific information on individual voltage regulators. Develop a schedule to check:

- Voltage.
- Electrical connections.
- Correct settings.
- Weather-tightness of the enclosure.
- Motor operation (also clean and lubricate).

Attachment 4

TYPICAL INSPECTION CHECKLISTS AND SCHEDULE DIESEL ENGINE GENERATING PLANTS

A4.1. Scheduled Inspection and Maintenance. When preparing an inspection schedule for a particular installation, follow the manufacturer's recommendations, especially during the warranty period. Determine if the units will be in continuous or intermittent service; if they operate at light or heavy loads; and if they operate under extremely dusty or dirty conditions. The following information is a compilation of manufacturers' recommendations and Air Force experience. These are the minimum actions to include in developing a class A plant inspection checklist and schedule. Adjust these checklists for other classes of generating plant.

A4.1.1. Operational Hourly Inspections. Observe and record performance data on AF Form 1167, **Daily Power Plant Operating Log (Diesel - Electric)**. Also, use local forms or the power plant log book to record during each shift the engine pressures, fuel pump rack positions, and fluid levels.

A4.1.2. Daily Inspections During Periods of Operation. Record applicable data on AF Form 1167. Perform the following and record using local forms or the power plant log book to track information necessary for operator consistency or future analysis.

- Check water, lube oil, fuel oil, and starting air systems for leaks.
- Open vents in water, lube oil, and fuel oil systems to relieve trapped air.
- Visually check high pressure fuel injection systems for leaks at connections and high pressure lines. Wear goggles during this check.
- Check water level in cooling water surge tank.
- Check alarm system with test switch.
- Drain water and sediment from starting air and fuel tanks.
- Hand-lubricate governor linkage and other wear parts not pressure lubricated. Check freedom of movement of fuel pump racks, linkage, and control shaft while engine is running.
- Wipe down engine.

A4.1.3. Inspection After Approximately 250 Hours of Operation (New or Overhauled):

- Once a week look for broken lockwires, loose bolts, oil leaks, water leaks from around lower liner seals, fuel leaks from fuel pump compartment, and general uncleanliness. Continue this procedure until the unit accumulates approximately 1000 hours of operation from initial start or since last overhaul.
- Inspect the cylinder head valve gear for proper lubrication of rocker bearings and valve stems.
- Check water pump glands and adjust to maintain a slight drip while unit is running.
- Check lubricating oil for water or fuel oil contamination. (Check visually using the settling and gage method.) Determine source of water or fuel.
- Visually check air intake filter screens or oil bath filter sump for dirt accumulation.
- Inspect radiators and radiator fans for dust accumulation and clean if necessary.

A4.1.4. Inspection After Approximately 1000 Hours of Operation:

- Inspect the internal crankcase every 1000 hours of operation.
- Check compression and firing pressures and enter results on AF Form 3508, **Diesel Cylinder Compression and Firing Tests**.
- Check inlet valve, exhaust valve, and injector-valve tappet clearance; adjust as needed. If valve-tappet clearance is correct after the first 1000 hours of operation, perform this check every 6 months.
- For engines with removable cam covers, inspect the camshaft cams and associated valve gear components for proper lubrication while operating the prelubrication pump. Check the cam for unusual wear and flat spots while the engine is not running.
- Check viscosity of the crankcase lube oil. Take a sample of lube oil for analysis.
- Check the governor drive gear for appearance and excessive backlash. For governors or actuators with independent oil pumps, drain and flush the device with the manufacturer's recommended cleaning solution. Refill with proper lubricant and compensate it.
- Check all safety devices and circuits.
- Check crankshaft deflection, crankshaft thrust clearance, and power takeoff alignment, including tightness of flywheel bolts. Record measurements on AF Form 731, **Crankshaft Deflection Record**. If readings are within manufacturer's allowable limits after the first 1000 hours of operation since initial start or last overhaul, perform this check every 6 months.
- Inspect the internal lower portion of the liner bore with the piston in the top position when checking the crankshaft. Check the exterior of main bearings, connecting rod crankpin bearing, and wrist pin area for bearing metal being squeezed out or discolored. Check for loose bearing caps. Check the rotor-to-stator air gap, and the main and connecting rod running oil clearance. Record measurements on AF Form 731. Do not disassemble bearings.
- Check condition and tension of all belts.
- Evaluate pressure differential across lube oil filter. Change filter elements if pressure differential approaches or exceeds manufacturer's recommendations.
- Evaluate pressure differential across fuel oil filter. Change filter elements if pressure differential approaches or exceeds the limit recommended by the manufacturer.

A4.1.5. Semiannual (or Approximately 4000 Hours of Operation) Inspection:

- Check foundation bolt nuts for tightness.
- Check tie rods (when applicable) for tightness.
- Check crankshaft deflection, thrust clearance, and power takeoff alignment; adjust as necessary. Record measurements on AF Form 731.
- On two-cycle engines, check inlet and exhaust ports for excessive carbon formation around the edges. Use access openings to ports (when present) to avoid removing the cylinder heads.
- Remove and clean thermocouples. Check pyrometer selector switch and junction boxes for proper electrical connections. Perform operational check of pyrometer selector switch while the engine is running.
- Check for scale in engine cooling water jackets.

- Test pressure, speed and temperature sensors and all alarm and shutdown devices. Record results in the operating log.

A4.1.6. Two-Year (or After Approximately 8000 Hours of Operation) Inspection:

A4.1.6.1. Perform the 1000-hour and 4000-hour inspections plus:

- Establish wear and wear rates (wear per 1000 hours) for all internal moving parts. Remove one cylinder head, piston, and connecting rod of the engine; then perform the following inspections.
- Measure the connecting rod journal size and roundness, and record measurements on the AF Form 3507, **Diesel Engine Inspection Data**.
- Ensure proper tightness of connecting rod bolts. Measure the inside diameter of connecting rod bearings (crankshaft end) for size and out-of-roundness. Record results on the AF Form 3507 to establish wear rate.
- Inspect bearing surfaces (shaft and bearing shell). Look for evidence of dirt and damage (for example, overheating, scoring, wiping, and broken out pieces of bearing metal in the shell). Record findings on the AF Form 3507. If the total wear of upper and lower shell halves is within permissible limits, you may interchange the shells with a given rod.
- Measure the piston pin for size and roundness, and general condition. Check oil supply holes for obstructions. Record measurements and findings on the AF Form 3507.
- Check inside diameter of wristpin bearing for size, out of roundness, and possible damage. Record measurements and findings on the AF Form 3507.
- Check the rifle-drilled hole (if present) in the connecting rod for obstructions.
- Check the cylinder liner bore for size and general condition of liner surface (lubrication, dry spots, scoring). Record measurements and findings on the AF Form 734, **Cylinder Liner and Ring Wear Record**.
- Check the outside diameter of the piston for size and roundness, and general condition. Check for dry spots, overheating, scoring, and accumulated carbon. Carefully inspect the pistons for cracks and general appearance. Record measurements and findings on the AF Form 3507.
- Check compression rings groove clearance. Do not remove the rings from the piston for cleaning and inspecting except when replacing or working on the rings. Measure the radial thickness of the rings and establish the wear rate. Measure the ring by installing in lower portion of spare liner. If worn more than about six to eight percent of the original thickness at any point or if the gap is more than three or four times the original gap, don't reuse the ring. Record measurements and findings on the AF Form 734 and the AF Form 3507.
- Check the condition of the oil control or scraper rings without removing the rings from the piston. The scraper edge should be sharp and free of nicks. If the land width of the scraper rings is about twice as wide as the original width, or has nicks or burrs, replace the ring. Check the oil drain holes in the piston for possible clogging with carbon or sludge. Record findings on the AF Form 3507.
- Inspect intake and exhaust valve seats for wear, pitting, and warping.

- Remove and inspect injection nozzle.
- Remove and inspect starting air valve (where present).
- The condition, wear, and wear rates of similar components in the remaining cylinders of an engine are normally about the same as those of the inspected cylinder. Determine the need to overhaul remaining cylinders on the basis of the established wear rates. You can estimate with reasonable certainty the replacement parts needed and the overhaul time required from the wear rates. Prepare for the overhaul while waiting for parts to arrive.

A4.1.6.2. Check the fuel regulating linkage for lost motion (wear) or binding.

A4.1.6.3. Check operation of pressure and temperature measuring devices, including thermostatically controlled valves; calibrate as necessary.

A4.1.6.4. Check condition of all gears and shafting, such as governor gears or chains, and pump drive gears or chains. Measure backlash or observe slack. Record measurement and findings in the log book.

A4.1.6.5. Use the manufacturer's checklist to inspect the starting air compressor and system. Record findings and action taken in the log book.

A4.1.6.6. Check internal condition of the lube oil cooler for leaks, scale buildup, corrosion and clogging (8000-hour inspection only).

A4.1.6.7. Inspect the turbocharger air impeller without dismounting. Remove air pipe section to turbo and inspect impeller for dirt accumulation. Spin rotor assembly by hand to check for smooth rotation.